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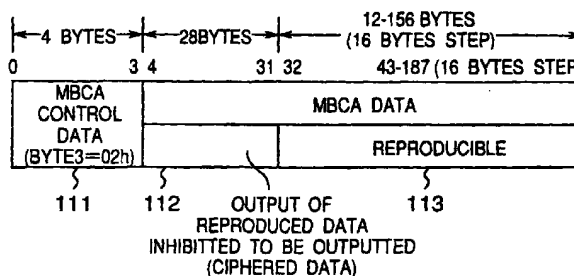
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(54) **Optical disk, method for recording and reproducing additional information to and from optical disk, reproducing apparatus for optical disk, and recording and reproducing apparatus for optical disk**

(57) An optical disk comprises a first recording area for recording contents data and data for recording and reproducing the contents data, and a second recording area for recording secondary data on the contents recorded in the first recording area, the secondary data being recorded as stripe marks longer in radial direction. Further, the second recording area comprises a first section for recording control data on the second recording area, a second section for recording data not to be inhibited to be outputted from a recording and reproducing apparatus for the optical disk, and a third section for recording data to be inhibited to be outputted from a recording and reproducing apparatus. The control data recorded in the first section includes an identifier which shows whether said second recording area includes said third section or not. By using the data to be inhibited to be outputted in the second recording area, a copyright of contents is protected and illegal use of software is prevented.

*Fig.2B*



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## Description

### BACKGROUND OF THE INVENTION

### FIELD OF THE INVENTION

[0001] The present invention relates to an optical information recording medium such as an optical disk on which information can be recorded, reproduced or erased, a recording and reproducing method and a recording and reproducing apparatus therefor.

### DESCRIPTION OF PRIOR ART

[0002] Recently, as electronic computers and image processing systems are developed, an amount of information data to be processed and image processing speed are increased rapidly, and audio and visual data are digitalized. Then, an auxiliary storage device, which is not expensive, has a large capacity and can be accessed at a high speed, and a recording medium therefor, especially an optical disk, become popular rapidly.

[0003] A basic structure of a prior art magneto-optical disk, as an example of an optical disk, is as follows. A recording layer is formed via a dielectric layer on a disk substrate. Further, an intermediate dielectric layer and a reflection layer are formed on the recording layer successively, and an overcoat layer is formed thereon. Recording and erasing of information are performed with illumination of a laser beam to increase the temperature of the recording layer so as to change its magnetization, while reproduction of recorded signals is performed with illumination of a laser beam onto the recording layer by detecting rotation in polarization plane as a change in optical intensity due to the magneto-optical effect.

[0004] For optical disks such as DVD-ROM, DVD-RAM and DVD-R, information is formed as uneven pits on a substrate or two optically different states of the recording layer made of a phase-change material or an organic material. Further, a reflection layer and an overcoat layer are formed thereon. Then, a reproduction signal is detected as a difference between two states in the intensity of reflecting light due to the existence of a pit or due to structural or chemical change when the disk is illuminated with a laser beam.

[0005] For an optical disk, protection management of disk information is required to use additional information which can be used for copyright protection such as prohibition of copy or prevention of illegal use of a software. In the above-mentioned optical disks, it is possible to record disk information in the TOC (table of contents) area or the like which is a recording area for control data. However, when the disk information is recorded with prepits, it is managed for each stamper. Therefore it is a problem that the disk information cannot be managed for each user.

[0006] Further, when information is recorded with a magnetic film or a thin film made of a phase change material, the additional information can be changed or rewritten illegally easily. Therefore protection management for copyright of the contents in an optical disk or the like is not possible.

[0007] Further, when additional information is recorded with an irreversible recording technique, if it can be reproduced and outputted from the recording and reproducing apparatus, the additional information can be interpolated or processed. Therefore the management of main information becomes insufficient and that an illegal work may not be prevented.

### SUMMARY OF THE INVENTION

[0008] An object of the present invention is to provide an optical disk which can be used for copyright protection such as inhibition of copy or prevention of illegal use of a software.

[0009] Another object of the present invention is to provide a recording and reproduction method which can be used for copyright protection for an optical disk.

[0010] A further object of the present invention is to provide a reproducing apparatus, a recording apparatus and a recording and reproducing apparatus which can be used for copyright protection for the optical disk.

[0011] In one aspect of the invention, an optical disk according to the invention has a recording layer for recording information, and the recording layer disk comprises a first recording area for recording contents data and data for recording and reproducing the contents data, and a second recording area for recording secondary data on the contents recorded in the first recording area, the secondary data being recorded as stripe marks longer in radial direction. The second recording area comprises a first section for recording control data on the second recording area, a second section for recording data not to be inhibited to be outputted from a recording and reproducing apparatus for the optical disk, and a third section for recording data to be inhibited to be outputted from the recording and reproducing apparatus for the optical disk. Further, the control data recorded in the first section includes an identifier which shows whether the second recording area includes the third section or not. The data recorded in the second recording area are recorded, for example, as a plurality of data arrays arranged in the circumferential direction of the optical disk. According to the optical disk, the secondary data can be used for copyright protection such as prevention of illegal copy and of illegal use of software.

[0012] In a second aspect of the invention, a method reproducing contents from the above-mentioned disk comprises the steps of reproducing data from the second recording area before reproducing data from the first recording area, deciding, based on control data included in data reproduced from the second

recording area, whether the data reproduced from the second recording area include data to be inhibited to be outputted from a recording and reproducing apparatus for the optical disk to the external, and processing the data to be inhibited to be outputted only in the a recording and reproducing apparatus when the data reproduced from the second recording area are determined to include the data to be inhibited to be outputted, without outputting the data to be inhibited to be outputted.

**[0013]** In a third aspect of the invention, an apparatus for reproducing contents from the above-mentioned optical disk comprises an optical head which reproduces information from the optical disk with an optical spot, a first reproducing section which reproduces data with the optical head from the first recording area, and a second reproducing section which reproduces data with the optical head from the second recording area. When data to be inhibited to be outputted are recorded in the second recording area, the second reproducing section processes the data only therein.

**[0014]** In a fourth aspect of the invention, an apparatus for reproducing contents from the above-mentioned optical disk comprises an optical head which reproduces information from the optical disk with an optical spot, a first reproducing section which reproduces data with the optical head from the first recording area, and a second reproducing section which reproduces data with the optical head from the second recording area. When the second reproducing section generates information signals based on data to be inhibited to be outputted recorded in the second recording area, and the first reproducing section superposes the information signals to signals reproduced from the first recording area and outputs the superposed signals.

**[0015]** In a fifth aspect of the invention, a recording and reproducing apparatus for recording contents from the above-mentioned optical disk comprises a generator which generates information signals based on data inherent to the optical disk, recorded in the second recording area and inhibited to be outputted from the recording apparatus, and a recorder which superposes the generated information signals with predetermined signals and records the superposed signals to the first recording area or add them to the second recording area.

**[0016]** In a sixth aspect of the invention, a recording apparatus for recording contents to the above-mentioned optical disk comprises a cipher device which ciphers the contents based on data including information inherent to a disk, the information having been recorded in the second recording area, and a recording section which records the contents ciphered by the cipher device in the first recording area in the optical disk.

**[0017]** In a seventh aspect of the invention, a reproducing apparatus for reproducing contents from the above-mentioned optical disk comprises an optical head which reproduces information from the optical disk

with an optical spot, a first reproducing section which reproduces data with the optical head from the first recording area, and a second reproducing section which reproduces data with the optical head from the second recording area. The the first reproducing section decodes the ciphered contents data by using the disk identification reproduced by the second reproducing section.

**[0018]** In an eighth aspect of the invention, a reproducing apparatus for reproducing contents from the above-mentioned optical disk having the secondary data including a disk identification inherent to each optical disk comprises an optical head which reproduces information from the optical disk with an optical spot, a first reproducing section which reproduces data with the optical head from the first recording area, and a second reproducing section which reproduces data with the optical head from the second recording area. The second reproducing section comprises a device which suppresses high frequency components with cut-off frequency of 1.2 MHz PE-RZ decoder and decodes the secondary data after suppressing high frequency components by the device.

**[0019]** An advantage of the present invention is that by using additional data recorded in the second recording area in an optical disk, contents recorded in the first recording area can be protected strongly.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0020]** These and other objects and features of the present invention will become clear from the following description taken in conjunction with the preferred embodiments thereof with reference to the accompanying drawings, and in which:

Figs. 1A, 1B and 1C are a plan view of an optical disk of an embodiment of the invention, a diagram of control data and a diagram of waveforms of signals on recording and on reproduction, respectively;

Figs. 2A and 2B are diagrams of physical format of additional information in an optical disk;

Figs. 3A and 3B are a sectional view of a magneto-optical disk of an embodiment of the invention and a diagram of a waveform of signals on recording and on reproduction;

Fig. 4 is a schematic plan view of a magneto-optical disk using magnetic super-resolution and a diagram of reproduced signals;

Fig. 5A is a block diagram of a recording apparatus for additional information in the embodiment of the invention, and Fig. 5B is a perspective view of a laser section of the recording apparatus for additional information;

Fig. 6 is a diagram of a Kerr hysteresis loop in a direction perpendicular to a film plane of a BCA subjected to heat treatment and a non-BCA not

subjected to heat treatment in a recording layer in a magneto-optical disk;

Fig. 7 is a block diagram of a recording and reproducing apparatus for a magneto-optical disk;

Fig. 8 is a diagram of an optical structure of the recording and reproducing apparatus for a magneto-optical disk;

Figs. 9A and 9B are trace diagrams of a waveform of difference signal of BCA signal and that of addition signal when recording current for the disk is 8 A;

Figs. 10A and 10B are parts of a flowchart of reproduction of additional information including signals inhibited for output of an optical disk;

Fig. 11 is a diagram of a system including an optical disk drive and a personal computer;

Fig. 12 is a flowchart of demodulation of MBCA signals;

Fig. 13 is a flowchart of MBCA reproduction;

Figs. 14A, 14B and 14C are a plan view of an optical disk of a second embodiment of the invention, a diagram of a waveform of signals of additional information on recording and on reproduction, and a plan view of another optical disk;

Fig. 15 is a diagram of a reproduction circuit for BCA data;

Fig. 16A, 16B and 16C are graphs of reproduction signal, converter input signal and binarized signal in the reproduction circuit; and

Fig. 17 is a graph of BCA modulation noises plotted against cut-off frequency of a low-pass filter.

Fig. 18 is a block diagram of a disk production section in an apparatus for reproducing an optical disk;

Fig. 19 is a block diagram of an apparatus for manufacturing a disk of a contents provider and a reproducing apparatus of a system operator;

Fig. 20 is a block diagram of a recording and reproducing apparatus for an optical disk;

Fig. 21 is a block diagram of an entire retransmission apparatus and a reproducing apparatus of a system operator;

Figs. 22A - 22H are diagrams of waveforms in time axis and in frequency axis of original signals and image signals;

Fig. 23 is a block diagram of a receiver of a user and a transmitter of a system operator; and

Fig. 24 is a block diagram of a watermark detector of an optical disk.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0021] Referring now to the drawings, wherein like reference characters designate like or corresponding parts throughout the several views, the invention will be explained below in detail with reference to embodiments. First, a structure of an optical disk according to an embodiment of the present invention will be

explained. Fig. 1A is a plan view of the optical disk. The optical disk 100 includes a main information area for recording main information 110 and an additional information area for recording additional information 101.

The main information area has a lead-in area and a TOC area (not shown) as in prior art optical disks. When data are recorded or reproduced, the lead-in area is focused on, and after the reproduction becomes possible, the control data (TOC) 103 of the main information are reproduced from the TOC area. The control data are formed, for example, as pit signals. The additional information area is located at a predetermined area in the inner peripheral portion of the optical disk, but it may be located at a predetermined area in the outer peripheral portion thereof. The additional information is formed as marks of stripes longer in the radial direction (similar to a bar code) and visible for naked eye. The main information is data (contents) recorded or reproduced by a user, for example, compressed video signal of a moving picture. The additional data are not directly necessary for recording or reproducing the main information, and the main information can be recorded or reproduced even when the additional information is not recorded. The additional information is data such as a serial number which is recorded when the optical disk is fabricated, and it can include management information which can be used for copyright protection such as prohibition of copy or prevention of illegal use of a software. As will be explained later, a part of the additional information may have data to be inhibited to be outputted from a recording and reproducing apparatus.

[0022] As shown in Fig. 1B, the control data 103 in the main information in the TOC area in the optical disk includes data on the additional data. The data includes a stripe data identifier 104, a stripe recording capacity, an additional stripe data identifier 105, and a stripe back side identifier 106.

[0023] The stripe data identifier 104 shows the existence of additional information. When an optical disk is reproduced, by reproducing the TOC, it is decided according to the stripe data identifier 104 whether additional data (stripes) are recorded or not, so that the additional data 101 can be reproduced surely.

[0024] The additional stripe data identifier 105 shows the existence of a part of additional information added at a later time. Because the additional stripe data identifier 105 and the stripe recording capacity are recorded, when additional information 101 at the first trimming time is already recorded, the maximum capacity which can be recorded for additional information 107 at the second trimming time can be calculated. Then, when a recorder for additional information records additional information 107 at the second trimming time according to the TOC data, the maximum capacity thereof can be decided. Thus, it can be prevented that recording is performed over 360° to destroy the additional information 101 recorded at the first trimming time. As shown in Fig. 1A, by providing a space 108

equal to or larger than one frame of pit signals between the additional information 101 recorded in the first trimming time and that 107 recorded in the second one, it can be prevented that the previous additional information is destroyed.

**[0025]** The stripe back side identifier 106 shows the existence of additional information recorded at the back side of the optical disk. By using the identifier, the barcode-like additional information 101 can be reproduced surely even far an optical disk of double side type such as DVD. Further, data can be read from the back side when the stripes of the additional data extend through the two reflecting films, it can be decided whether the additional information is recorded at the back side opposite to a side from which data are reproduced. When the additional information is recorded at the back side of the optical disk, the recording layer at the back side is reproduced.

**[0026]** Further, when an addition times identifier (not shown) is recorded, data can be discriminated between the stripes or additional information 101 at the first time and those 107 at the second time. Therefore, additional recording becomes impossible.

**[0027]** Next, a format structure of additional information is explained. Fig. 2 shows a physical format of additional information provided as MBCA signals in an optical disk. The MBCA signals include control data 111. The control data 111 is set as 4-byte synchronization code. If the shortest recording period is set to 30  $\mu\text{m}$  and the largest radius is set to 23.5 mm, the memory capacity off the additional information is limited to 188 bytes or less after formatting. An identifier in the control data 111 discriminates a case (A) when all the MBCA data 113 can be reproduced to be outputted, and a case (B) when an information 112 inhibited to be outputted on reproduction is included. Thus, it can be easily discriminated according to the control data 111 included in the additional information (stripe signals) whether the optical disk includes signals 112 inhibited to be outputted from a recording and reproducing apparatus. If byte 4 in the control data is "00000000", all the additional information can be reproduced and outputted from the recording and reproducing apparatus, while if it is "00000010", 28-byte additional information 112 among the 188-byte additional information is inhibited to be outputted from the recording and reproducing apparatus. Further, the data 112 are recorded as ciphered data. Therefore, only the remaining 144-byte data 113 can be outputted to the external. A reproducing apparatus of optical disk set a protective safety mode for recorded information in the optical disk, as will be explained later. Thus, by using the ciphered information 112 inhibited to be outputted on reproduction, an optical disk and a reproducing apparatus therefor can protect files and prevent illegal copies according to additional information. Then, the protection and access right of management information of a person, a company or the like can be enhanced very much, and information such as data

files can be protected, for example, by preventing illegal outflow of information.

**[0028]** In concrete, the data 112 inhibited to be outputted from a recording and reproducing apparatus includes a part of identification (ID) information of the disk, a part of ciphered ID information, a part of information on a secret key for deciphering the ciphered ID information or a key for descrambling the main information based on ID information. Because a user cannot reproduce a part of the additional information, illegal processing or interpolation of the additional information such as MBCA data become difficult.

**[0029]** Next, an operation for an optical disk having the above-mentioned structure is explained below. For an optical disk having the recording layer as a perpendicular magnetization layer having magneto-optical effect, recording and erasing are performed by heating the recording layer locally with a laser beam to a temperature above the compensation temperature having a low coercive force, or above a temperature around the Curie temperature in order to decrease the coercive force of the recording layer around the irradiated portion, and by magnetizing it in a direction of the external magnetic field. (That is, information is recorded with so-called "thermo-magnetic recording".) Reproduction of the recorded signal is performed by heating the recording layer locally with a laser beam having a smaller intensity than the counterpart on recording or on erasing, and a rotation in the polarization plane of the reflecting or transmitting light according to the direction of magnetization is detected with an analyzer as a change in optical intensity. The rotation is caused by a magneto-optical effect such as Kerr effect or Faraday effect. In this case, in order to realize high density recording by decreasing interference between reverse magnetizations, a magnetic material having perpendicular anisotropic magnetization is used as the recording layer in the optical disk. As a material of the recording layer, a material is used which can record information by inducing temperature rise or chemical change due to light absorption when a laser beam is irradiated. On reproduction, a local change in the recording layer is detected with a laser beam having an intensity or frequency different from that on recording, and a reproduction signal is detected according to the reflecting or transmitting light.

**[0030]** Fig. 3A is a sectional view of a structure of the magneto-optical disk. On a disk substrate 131, a recording layer is formed via a dielectric layer 132, and the recording layer has a three-layer structure consisting of a reproduction magnetic film 133, an intermediate insulating film 134 and a recording magnetic film 135. The recording layer comprises a plurality of layered magnetic thin films made of different materials or compositions, the thin films having exchange coupling or static-magnetic field coupling between them. In this structure, a reproduction signal is detected by increasing a signal level on reproduction. An intermediate die-

lectric layer 136 and a reflection layer 137 are formed successively on the recording layer, and an overcoat layer 138 is formed further thereon. In the recording layer, a plurality of BCAs 120a and 120b are formed along the circumferential direction. BCA (Burst Cutting Area) denotes an area where stripe-like marks longer in the radial direction are formed (similar to a barcode).

**[0031]** Next, a method is explained for producing the magneto-optical disk. First, a disk substrate 131 having guide grooves or prebits for tracking guide is produced with injection molding for a polycarbonate resin. Next, a dielectric layer 132 of SiN film of thickness 80 nm is formed on the disk substrate 131 with reactive sputtering with a silicon target in an environment including argon and nitrogen gas. A recording layer consists of a reproduction magnetic film 133 made of GdFeCo film having Curie temperature  $T_{c1}$ , compensation composition temperature  $T_{comp1}$  and coercive force  $H_{c1}$ , an intermediate insulating film 134 made of SiN film as a nonmagnetic dielectric film and a recording magnetic film 135 made of TbFeCo film having Curie temperature  $T_{c2}$  and coercive force  $H_{c2}$ . On the dielectric layer 132, the magnetic films are formed with DC sputtering with an alloy target in an argon atmosphere, and the non-magnetic dielectric layer is formed with reactive sputtering with a silicon target in an environment including argon and nitrogen gas. The layers in the recording layer are formed successively. Next, an intermediate dielectric layer 136 made of SiN film of thickness 20 nm is formed on the recording layer with reactive sputtering with a silicon target in an environment including argon and nitrogen gas. Next, a reflecting layer 137 made of AlTi film of thickness 40 nm is formed on the intermediate dielectric layer 136 with DC sputtering with an AlTi target in an argon atmosphere. Finally, an ultra-violet-rays setting resin is applied to the reflecting layer 137 by dropping it on the reflecting layer 137 and by rotating it with a spinner at a revolution of 3,000 rpm, and it is set with ultra-violet-rays to form an overcoat layer 138 of film thickness of 8  $\mu$ m.

**[0032]** In the recording layer in the magneto-optical disk, the reproduction magnetic film 133 has film thickness of 40 nm and a composition having Curie temperature  $T_{c1}$  of 320 °C, compensation composition temperature  $T_{comp}$  of 310 °C and magnetic anisotropy in a direction in a film plane at room temperature. The intermediate insulating film 134 is a nonmagnetic SiN film of film thickness of 20 nm. The recording magnetic film 135 has film thickness of 50 nm, Curie temperature  $T_{c3}$  of 280 °C, and coercive force  $H_{c3}$  at room temperature of 18 kOe.

**[0033]** Next, the principle of reproduction in the three-layer-structure recording layer is explained with reference to Fig. 4. A recording domain 130 of information signal is recorded in the recording magnetic film 135. At room temperature, the reproduction magnetic film 133 has magnetic anisotropy along a direction in the film plane, and the magnetization in the recording

magnetic film 135 is small. Then, the static magnetic field from the recording magnetic film 135 is remained insulating by the intermediate insulating film 134, and the magnetization is not transferred to the reproduction magnetic film 133. Therefore, when a signal is reproduced, as to a low temperature portion 129b in the laser light spot 129a, a signal in the recording magnetic film 135 is not transferred to the reproduction magnetic film 135. However, as to a high temperature portion 129c in the laser light spot 129a, the temperature of the reproduction magnetic film 133 is increased to about the compensation composition temperature, and this decreases the magnetization of the reproduction magnetic film 133 to induce magnetization in the film normal direction. Further, the magnetization of the recording magnetic film 135 is increased due to temperature rise, so that magnetic coupling due to static magnetic field is effective. Thus, the magnetization direction in the reproduction magnetic film 133 is transferred in the direction of recording magnetic layer 135. Then, the recording domain 130 of information signal is masked as to the low temperature portion 129b in a part of the laser light spot 129a. Therefore, the recording signal is reproduced only from the high temperature portion 129c in the center of the laser light spot 129a. In this reproduction method, the static magnetic field is exerted through the intermediate insulating film 134 provided between the reproduction magnetic film 133 and the recording magnetic film 135, and the signal of the recording magnetic layer 135 is transferred to the reproduction magnetic film 133 only from the high temperature portion in the center of the light spot 129a. This is a magnetic super-resolution method called as "CAD" using static magnetic field, where a signal is reproduced only from a central portion having a high temperature caused by the laser light spot. By using this method, a signal can be reproduced from an area smaller than the laser light spot. Reproduction is also possible by magnetic super-resolution methods using exchange coupling between the magnetic layers, called as "FAD" where a signal is reproduced only from a low temperature portion in the laser light spot, or called as "RAD", where a signal is reproduced only from a high temperature portion in the laser light spot.

**[0034]** Next, a method of recording additional information to the magneto-optical disk is explained with reference to Fig. 5. Fig. 5A is a block diagram of a recording apparatus for additional information, and Fig. 5B is a diagram of an optical structure of the recording apparatus. For the compatibility with a recording and reproducing apparatus for a DVD disk, RZ (Return to Zero) recording method is used for recording additional information, and the format of recording signals also has compatibility.

**[0035]** First, by using a magnetization apparatus (not shown), the direction of the magnetization in the recording layer in the magneto-optical disk is arranged in one direction. Because the recording magnetic film

135 is a perpendicular magnetization film having coercive force of 18 kOe, the intensity of magnetic field of an electromagnet in the magnetization apparatus is set to 20 kilogauss. By moving the magneto-optical disk before the magnetization apparatus, the direction of the magnetization in the recording layer can be arranged in one direction. A disk identification (ID) generated by a serial number generator 408 is inputted to an input section 409, and the disk ID is ciphered by a cipher encoder 430 and encoded by an ECC encoder 407. Next, it is modulated by a PE-RZ modulator 410 according to modulation clocks and sent to a laser driver 411. Next, as shown in the light condensing section 414 in the laser recording device shown in Fig. 5B, a laser 412 such as a YAG laser having a high output power and a lens 417 such as a cylindrical lens for converging the light in a direction are used to converge a laser beam of a stripe-like rectangle longer in the radial direction on the recording layer, and a plurality of BCAs 120a and 120b are formed along circumferential direction of the disk. As to the recorded signals, the BCAs 120a and 120b are detected with a BCA reader (not shown) and subjected to PE (phase encoding) decoding. Then, it is compared with the recorded data, and if they agree with each other, the recording of the additional information is completed. In the magneto-optical disk, a width of fluctuation in reflectance is within 10 %. Therefore, focus control and the like are not affected.

**[0036]** Next, the principle of reproduction of BCA signals or additional information is explained. Fig. 6 shows a Kerr hysteresis loop in a direction perpendicular to a film plane of BCAs 120a, 120b, and non-BCAs 120c, 120d (Fig. 3A). It is found that the Kerr rotation angle and the anisotropy of perpendicular magnetization of the BCA 120a subjected to heat treatment are deteriorated to a large extent. Because the BCA 120a has low anisotropy of perpendicular magnetization because of the heat treatment with irradiation of laser beam (or the magnetic anisotropy in the film plane is dominant), the remnant magnetization vanishes in the film normal direction. Then, the magneto-optical recording cannot be performed, and a detection signal is not outputted. However, if a portion other than the BCA in the recording layer or the non-BCA is irradiated, because the portion is magnetized in the film normal direction, the polarization plane of the reflection light is rotated, and a differential signal of a photodetector (PD) divided into two areas is outputted. As shown in Fig. 3B, a reproduction waveform of the additional information can be obtained from the differential signal due to the rotation of the polarization plane. As explained above, from the BCA reproduction signal, the signal of additional information of the BCAs can be detected with an optical head for recording and reproducing a magneto-optical disk.

**[0037]** By using a BCA trimming device of Matsushita Electric Industry, a BCA recording device (CWQ pulse recording with YAG laser 50 W lamp excitation),

having a structure shown in Fig. 5, BCA signals are recorded actually at a recording power of BCA recording for a magneto-optical disk from a light-entering side of the disk.

**[0038]** Next, a recording and reproducing apparatus is explained with reference to Figs. 7 and 8. For an optical disk such as DVD-ROM, DVD-RAM or DVD-R, the structure and detection method of reproduction signals are different from the optical head shown in Fig. 8, but the basic structure and the basic operation of a reproducing apparatus for an optical disk are common, as shown in Fig. 7.

**[0039]** Fig. 8 shows an optical structure of a recording and reproducing apparatus for a magneto-optical disk. In an optical head 155, a laser beam of linear polarization emitted from a laser light source 141 is converted by a collimating lens 142 to become a laser beam of collimated light. Only P polarization in the laser beam transmits a polarization beam splitter 143, is condensed by an object lens 144, to irradiate the recording layer in the magneto-optical disk 140. Information of ordinary recording data (main information) is recorded by partially changing the directions (or up and down directions) of magnetization in the perpendicular magnetization film, and the reflecting (or transmitting) light from the magneto-optical disk 140 is changed as to rotation in the polarization plane according to the magnetization state due to the magneto-optical effect. The reflecting light with the polarization light with rotated polarization plane is reflected by the polarized beam splitter 143, and separated by a half mirror 146 in the signal reproduction direction and in the focus tracking control direction. After the light separated in the signal reproduction direction is rotated by 45° in the polarization plane by a  $\lambda/4$  plate 147, the P and S polarization components are separated by a polarized beam splitter 148 along respective propagation directions. The lights separated in two directions are detected by photodetectors 149 and 150. Then, the change in rotation in the polarization plane is detected as a differential signal of the light intensities detected by photodetectors 149 and 150, and a reproduction signal of the data information is obtained from the differential signal. Further, the light in the focus tracking control direction separated by a half mirror 146 is used by a focus tracking photosensing portion 153 for focus control and for tracking control. A magnetic head 151 is driven by a driver 152.

**[0040]** A BCA as additional information in the magneto-optical disk is detected with a reproduction method similar to the main information. The BCAs 120a, 120b subjected to heat treatment are deteriorated on the perpendicular magnetic anisotropy to a large extent (refer to hysteresis loop 120a in Fig. 6). Because the direction of the magnetization in the perpendicular magnetization film is arranged in the one direction when the magnetic layer is fabricated or the signals are reproduced, the laser beam incident on the non-BCAs 120c, 120d having large perpendicular magnetic anisotropy and not

subjected to heat treatment is rotated by  $\theta_k$  in a direction to be reflected. On the other hand, because the BCAs 120a, 120b subjected to heat treatment and having deteriorated perpendicular magnetic anisotropy has a very small Kerr rotation angle, the incident laser beam is reflected without rotated on its polarization plane.

**[0041]** In the recording and reproducing apparatus for a magneto-optical disk shown in Fig. 7, as a method for arranging the direction of the magnetization in the perpendicular magnetization film in one direction when the BCAs are reproduced, a laser light equal to or larger than 4 mW is irradiated to heat the recording magnetic film 135 in the recording layer in the magneto-optical disk 140 above the Curie temperature, while a constant magnetic field equal to or higher than 100 Oe is applied by the magnetic head 151 to the magneto-optical disk 140. As a result, the additional information in the BCAs are detected by a differential signal which is similar to that for the main information as a change in the polarization direction in the recording layer.

**[0042]** In this embodiment, the additional information is detected from the differential signal as explained above. By using the reproduction method, a component of fluctuation of light intensity without light polarization can almost be cancelled. Then, it is advantageous for decreasing noises due to fluctuation of light intensity.

**[0043]** When the additional information is detected and a waveform photograph is traced, Fig. 9A shows a waveform photograph of the differential signal, and Fig. 9B shows that of the additional signal. As shown in Fig. 9A, it is found that a pulse waveform of BCA signals having a sufficient amplitude ratio is detected on the differential signal. The recording layer is changed only on the magnetic characteristics, and when a part of the recording layer is crystallized, a change in average refractive index is equal to or smaller than 5 %, so that a change in the intensity of reflecting light from the magneto-optical disk is equal to or smaller than 10 %. Therefore, a change in reproduction waveform caused by the change in the intensity of reflecting light is very small. At this time, reproduction waveforms as shown in Figs. 9A and 9B are obtained by setting recording current of laser light to 8 - 9 A, and a BCA image is observed not with an optical microscope, but only with a polarization microscope.

**[0044]** In the above-mentioned embodiment, after the direction of magnetization of the recording magnetic film 135 in the recording layer is aligned along one direction (or magnetized), BCA signals as additional information are recorded, or by using a recording and reproducing apparatus, a laser light is irradiated to a disk to which BCA signals are recorded while applying a magnetic field in a direction. It is also possible to align the direction of the magnetization of the perpendicular magnetization film in the recording layer in a direction. The recording layer 135 in the magneto-optical disk has coercive force of 18 kOe at room temperature. When the temperature is increased to 100 °C or above by irra-

diation with a strobe light, a laser beam or the like, the coercive force is decreased to 6 kOe or less. Then, the direction of magnetization in the recording layer is aligned in a direction by applying a magnetic field equal to or higher than 8 kOe which is larger than the counter-part at room temperature.

**[0045]** In this embodiment, the recording layer has the three layer structure consisting of the reproduction magnetic layer 133, the intermediate insulating film 134 and the recording magnetic film 135. However, additional information can be recording at least by remarkably decreasing the magnetic anisotropy in a direction normal to the film plane of a portion in the recording magnetic film 135 subjected to heat treatment so that magnetic anisotropy in the plane is dominant.

**[0046]** Further, a similar effect is obtained even when the perpendicular magnetic anisotropy in at least one of the reproduction magnetic film 133 and the perpendicular magnetic film 135 is deteriorated, or when the perpendicular magnetic anisotropy in all the magnetic layers of the reproduction magnetic film 133, the intermediate magnetic film 134 and the perpendicular magnetic film 135 is deteriorated.

**[0047]** The curie temperature, coercive force and the like of the magnetic films in the recording layer can be changed easily by selection of composition and addition of various elements having different magnitudes of magnetic anisotropy. Therefore, according to the recording and reproduction conditions to be required for a magneto-optical disk, the structure and the fabrication conditions of the recording layer in a magneto-optical disk, and the recording conditions of additional information can be set appropriately.

**[0048]** In the above-mentioned optical disk, the disk substrate 131 is made of a polycarbonate resin, the dielectric layers 132 and 136 are made of a SiN film, and the magnetic films are made of a GdFeCo film, a TbFe film, and a TbFeCo film. However, the disk substrate 131 may be made of a glass or a plastics such as a polyolefin or PMMA. The dielectric layers 132 and 136 may be made of a different nitride film such as AlN, an oxide film such as TaO<sub>2</sub>, a chalcogenide film such as ZnS, or a mixture thereof. The magnetic films may be made of a ferrimagnetic film, including a rare earth and a transition metal, having different materials or a composition, or a magnetic material having perpendicular magnetic anisotropy such as MnBi or PtCo. The structure or the magnetic layer may be a structure made of only one layer or a multi-layer structure.

**[0049]** Fig. 10 shows a flowchart of a reproduction procedure using additional information. When an optical disk is inserted (step 302), focus and tracking are set first (step 301a). For a normal disk, the lead-in area is focused on so that the reproduction becomes possible (step 301b), and the TOC (Control Data) is reproduced (step 301c). When the lead-in area or the TOC is not reproduced, the flow stops as an error.

**[0050]** As shown in Fig. 1B, in an optical disk of the

invention, a stripe identifier 104 is recorded in the TOC in the TOC area 103 in the main information. Therefore, when the TOC is reproduced, it can be decided that the stripe is recorded or not. Thus, it is decided whether the stripe identifier 104 is 0 or 1 (step 301d). When the stripe identifier 104 is 0, the optical head moves to the outer periphery of the optical disk (step 303), and the rotation phase control is performed to reproduce data in the data area 110 of the ordinary main information (step 303).

**[0051]** The identifier in the main information for the existence of the additional information is detected based on a detection signal detected by one photodetector or on a sum signal of detection signals detected by a plurality of photodetectors in the optical head. If the existence of the additional information is determined according to the identifier, the optical head is moved to a predetermined position in the optical disk where the additional information is recorded. Thus, the stripes, defects and the like in the additional information can be detected easily. Therefore, the run-up time of the apparatus can be shortened, and the reproduction of the additional information has compatibility among optical disks using different reproduction methods.

**[0052]** When the stripe identifier 104 is 1, it is decided for a double-side disk such as DVD-ROM whether data are recorded in a side opposite to a side from which the stripe is reproduced, or whether a back side identifier 106 is 1 or 0 (step 301e). If the back side identifier 106 is 1, the recording layer in the back side is reproduced (step 301p). For a magneto-optical disk of single-side structure, the back side identifier 106 is always 0. If the reproducing apparatus cannot reproduce the back side of an optical disk automatically, a message of "please instruct back-side reproduction" is displayed. When stripes are found to be recorded in the side under reproduction at steps 301d and 301e, the optical head is moved to a region 101 of stripes at an inner side in the optical disk, the rotation speed is controlled, and the signal 111 in the TOC region of stripes are reproduced in CAV (constant angular velocity) rotation (step 301f).

**[0053]** By reproducing the signals 111 in the TOC area on stripes, if the stripes do not have a region 112 where the output from the recording and reproducing apparatus is inhibited (step 301g), stripe signals 113 are reproduced (step 304a). Next, it is decided whether the reproduction of the stripe signals 113 is completed or not (step 304b). When the reproduction of the stripe signals 113 is completed, the optical head moves to an outer peripheral of the optical disk (step 304c), and pit signals added with the stripe signals 113 or data of main information are reproduced (step 204d).

**[0054]** By reproducing signals 111 in the TOC area on stripes, if the stripes have the region 112 where the output from the recording and reproducing apparatus is inhibited (step 301g), protective safety mode for recording information in the disk is started to be set. First, a

command of protective safety mode is set, and the remaining additional information 112, 113 is reproduced (step 301h). If a protective safety mode other than a command which can be set is set for an optical disk, an error occurs, and the disk reproduction is stopped.

**[0055]** When a command of protective safety mode is set and reproduction of additional information 112, 113 is completed (step 301i), a secret key is detected from an enciphered media ID (step 301j). The media ID is a signal recorded by ciphering or modulating information and it is inhibited to be outputted from the recording and reproducing apparatus. Therefore, it cannot be reproduced by a user when the disk is reproduced. Next, by using the secret key or information signals produced by using it, a reproduction command on a data file to be protected is set (step 301k). If a protective safety mode which cannot be set is instructed to be set for the data file in the optical disk, the reproduction mode cannot be entered. When the reproduction command for a data file to be protected is set, decoding of the protected file is started (step 301l). When the decoding of the protected file is not completed, the above processes from the confirmation of the secret key (step 301k) are repeated. If the reproduction command for the protected file cannot be set by a predetermined times or more, an error occurs, and the reproduction of the disk is stopped (step 301m). When the decoding is completed, the file is closed. Then, the protective safety mode is canceled (step 301n), and data of main information other than the protected file are allowed to be reproduced.

**[0056]** When the decoding is not completed (step 301m), the above processes are repeated from the setting of reproduction command for the data (step 301k).

**[0057]** When the reproduction of the stripes or additional information 101 is completed and the protective safety mode is canceled (step 301n), the optical head is moved to the outer periphery of the optical disk (step 303). Then, and the rotation phase control is started again, and data of ordinary pit signals and signals of the main information are reproduced.

**[0058]** As explained above, by recording the stripe identifier 104 in the pit area in TOC or the like, the stripes or additional information 101 can be reproduced surely. Further, according to the control data 111 included in the stripe signals, it is decided easily whether the optical disk includes the signals 112 which inhibits a part of the additional information of the stripes to be outputted from the recording and reproducing apparatus.

**[0059]** Fig. 11 shows a system comprising an optical disk recording and reproducing apparatus and a personal computer. An optical disk recording and reproducing apparatus 320 sends information of an optical disk 140 through an interface 321 such as a small computer system interface (SCSI) to a personal computer 322. The information is processed by a central processing unit (CPU) 323 in the computer 322 and